Effects of Climate Change on Vegetation in the Rock Creek Drainage at Denali National Park, Alaska

The vegetation element of the Denali long term ecological monitoring program was originally designed to monitor the effects of climate change on the the position of the forest-tundra ecotone and to discern concomitant changes in the community structure of three major vegetation types occuring in the northern part of the Park (spruce forest, treeline spruce-birch scrub woodland, and alpine tundra). The initial effort thus established permanent monitoring sites along an elevation gradient, with a site located in each of these three vegetation types. At each site, the initial structure and composition of the tree, shrub and herbaceous strata were documented to provide baseline data for comparison in future years. A principal objective of the project was to measure differences in white spruce (*Picea glauca*) growth and reproduction in different landscape positions over time and relate trends in these parameters to changes in the position of treeline on the landscape. This monitoring program was intended to help park managers document and anticipate the direction and trajectory of major changes in ecosystems fundamental to Park resources that are expected to occur in the coming decades as a result of climate change.

The Park staff is working in cooperation with Biological Resources Division personnel in order to transform the scope and character of the vegetation-monitoring program so that it will address a broader array of management needs. However, Park personnel continue to carry out the field work outlined in the original monitoring protocol. In addition, many of the data gathered at the start of this project were analyzed and summarized this year. Indeed, these data are now being used to aid in the development of new sampling plans and vegetation monitoring protocols for the Park. In summary, work on the vegetation component of the Denali LTEM program proceeded along three primary tracks during 1998:

1) analysis, summarization and evaluation of existing vegetation data
2) routine collection and archiving of field data from study sites in the Rock Creek watershed
3) development and modification of vegetation monitoring goals, protocols and procedures

1998 Results

We collected field data documenting berry productivity, spruce growth, and spruce cone and seed production within permanent vegetation plots in 1998. The most notable result from 1998 fieldwork was the documentation of a banner year for spruce cone production (see **fig. 1**). The mean number of cones produced per tree was 390 at the forest site in 1998. This is more than four times the number of cones per tree that were observed during the previous high year for the forest site, which was 1992. The mean number of cones per tree at the treeline site was 162 in 1998. This is more than three times more cones per tree than were observed in 1993, the previous high year for cone production there.

Yearly increases in the diameter of spruce trees in vegetation plots at the forest and treeline sites are recorded by dendrometers. These data show that the rate of spruce growth had generally been on the increase at both sites during the four years prior to 1998, and that this year's growth rate was considerably lower (**fig. 2**). This clearly illustrates a shift in the allocation of resources from growth to reproduction by spruce in the study area during the 1998 growing season. The demand for resources made by the large crop of growing and maturing cones likely resulted in reduced allocation to vegetative growth by these trees.

Banner spruce cone crops such as the one recorded this year are known to occur only episodically even in the lowlands, usually separated by long periods (up to 12 years) of negligible cone production. It is likely that these banner crops are even less frequent in mountainous areas such as Denali, where summers are relatively short and cool. While it is thought that warm, dry summer weather is a prerequisite for the initiation of a substantial cone crop, all the conditions that give rise to this phenomenon are not well known. Long term data from Denali, in combination with information from other stations (such as the Bonanza Creek long term ecological research facility near Fairbanks) will help identify the conditions that give rise to large spruce cone crops. The Denali station can make a unique contribution because there are no other long-term ecological monitoring stations located in the Alaska Range.

The 1998 cone crop presents a first opportunity to examine the meteorological conditions that may stimulate increased reproductive output by white spruce in the Alaska Range. Initiation of cones in white spruce takes place during the summer prior to the year in which the cones mature. Therefore the conditions that are most relevant to the formation of this years cones are those that occurred during the summer of 1997. A plot of cumulative thawing degree days for the months of June and July (departures of average daily temperature above 0° C; **fig. 3**) for the years 1991-1997 shows that warmer conditions prevailed during these months in 1997 than during any of the previous six years, beginning on the 28th of June and lasting for the remainder of the season. Precipitation sums, on the other hand, do not indicate that the summer of 1997 was particularly dry, as would be expected based on the hypothesis that warm *and* dry conditions are required for the stimulation of a large cone crop (**fig. 4**). In fact total April-July precipitation in 1997 was the second highest noted during this period. Further analyses integrating temperature, precipitation and other climatic parameters will be done in order to fully explore these relationships.

The formation of a large cone crop is not a guarantee of abundant spruce seed the following year. The second critical step in the production of a large spruce seed crop is the fertilization and maturation of the seeds within the cones. This takes place during the second summer of cone growth, and is also dependent on climatic factors. In other words, it is possible to have a very large cone crop produce only a paltry number of viable seed, if conditions during the second summer are not favorable. In order to quantify the relative productivity (in terms of viable seed) of the cones in the 1998 crop, we harvested cones directly from trees at eight widely scattered treeline sites at the end of the summer. These cones will be examined for the quantity and quality of seed they contain, providing a measure of the amount and variability in seed productivity and viability within and among eight different sites during a banner cone crop.

<u>Stand structure of permanent vegetation plots</u>

The episodic character of spruce reproduction affects the patterns of stand establishment of spruce on the landscape. It means that recruitment of spruce seedlings occurs: 1) relatively infrequently and 2) in "pulses" of relatively even-aged cohorts, as opposed to a steady, even accumulation of new seedlings. The episodic nature of spruce recruitment is magnified by the species preference for a mineral soil seedbed for successful establishment. The suitability of a potential seedbed is enhanced by certain types of disturbance, such as fire, that result in the exposure of a mineral soil surface. Hence, spruce is strongly benefited when a productive seed year coincides with a fire or other disturbance event. The third element necessary for successful establishment of a stand of spruce is suitable microclimatic conditions during the sensitive seedling stage.

A comparison of the size class distribution of white spruce individuals in the permanent vegetation plots at the forest site versus those in the treeline site reveals several differences in the population structure of spruce between these two sites (**figs. 5 and 6**). Most notably, these histograms indicate that significant seedling establishment occurred within the forest plots (prior to 1992, when these measurements were taken**; fig 5**) compared to little, if any, recent establishment of spruce in the treeline plots (**fig. 6**). This is evidenced by the large numbers of individuals in the less than 0 cm diameter (at 1.3 m above the ground) size class in the forest site and the very small number of individuals in these size classes at treeline. Furthermore, the size-class histogram for the treeline site shows that a majority of the trees in these plots are of a similar size. Thus these stands may be formed by one relatively even-aged cohort dating to a specific pulse of establishment (perhaps derived from a particular banner seed crop in the past). A project designed to determine the age-structure of the spruce trees in this area has been undertaken by a researcher from the University of Alaska.

If the cone crop of 1998 produces a large number of viable seeds in the treeline and forest sites, as expected, it will create the potential for a strong pulse of spruce establishment on the landscape. Will a significant number of seedlings become established in one or both of these landscape positions, even in the absence of disturbance? Continued monitoring of the permanent plots will document this potential shift in community structure. Alternatively, monitoring will demonstrate a lack of seedling recruitment even with the presence of abundant spruce seed, if that turns out to be the case.

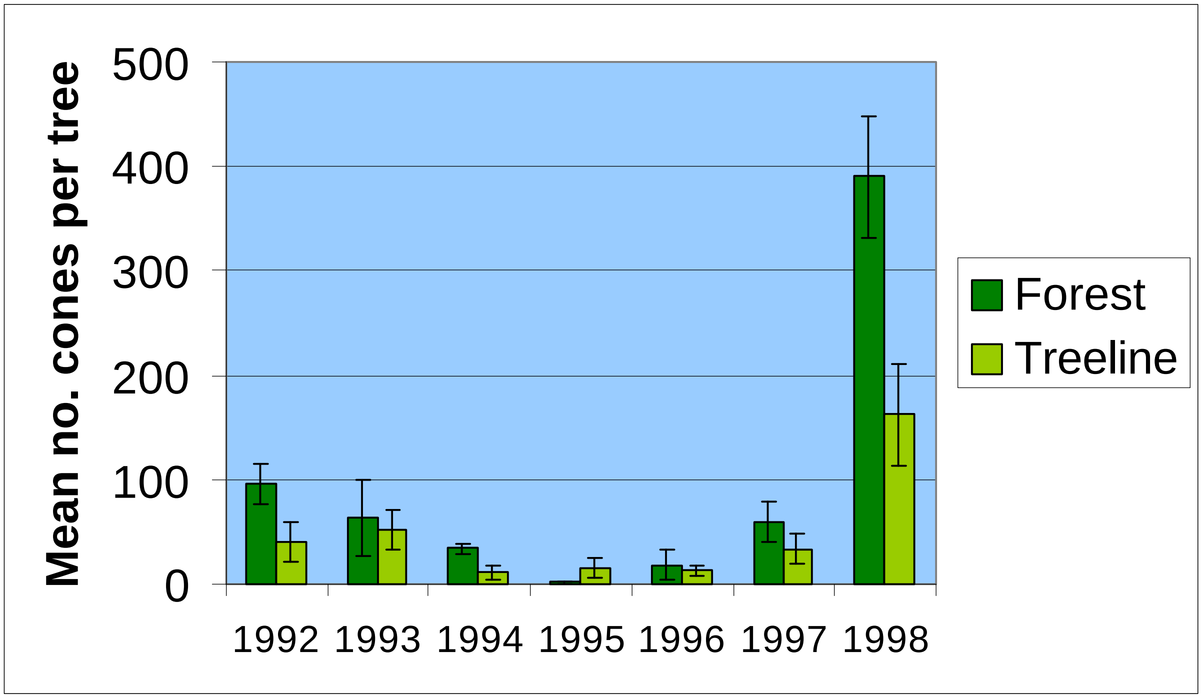

Figure 1. Mean number of cones per tree in forest and treeline sites in Rock Creek watershed, Denali National Park, Alaska (error bars give standard error).

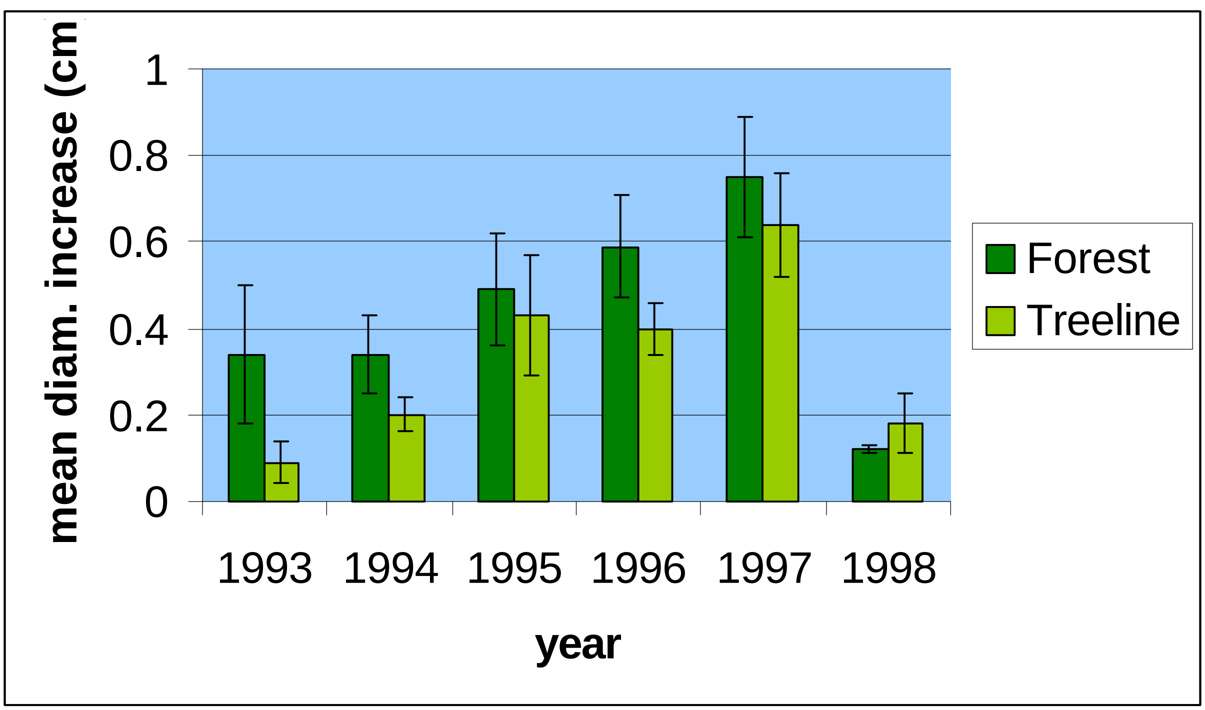

Figure 2. Mean increase in diameter of selected trees in forest and treeline sites Rock Creek watershed, Denali National Park, Alaska (error bars give standard error).

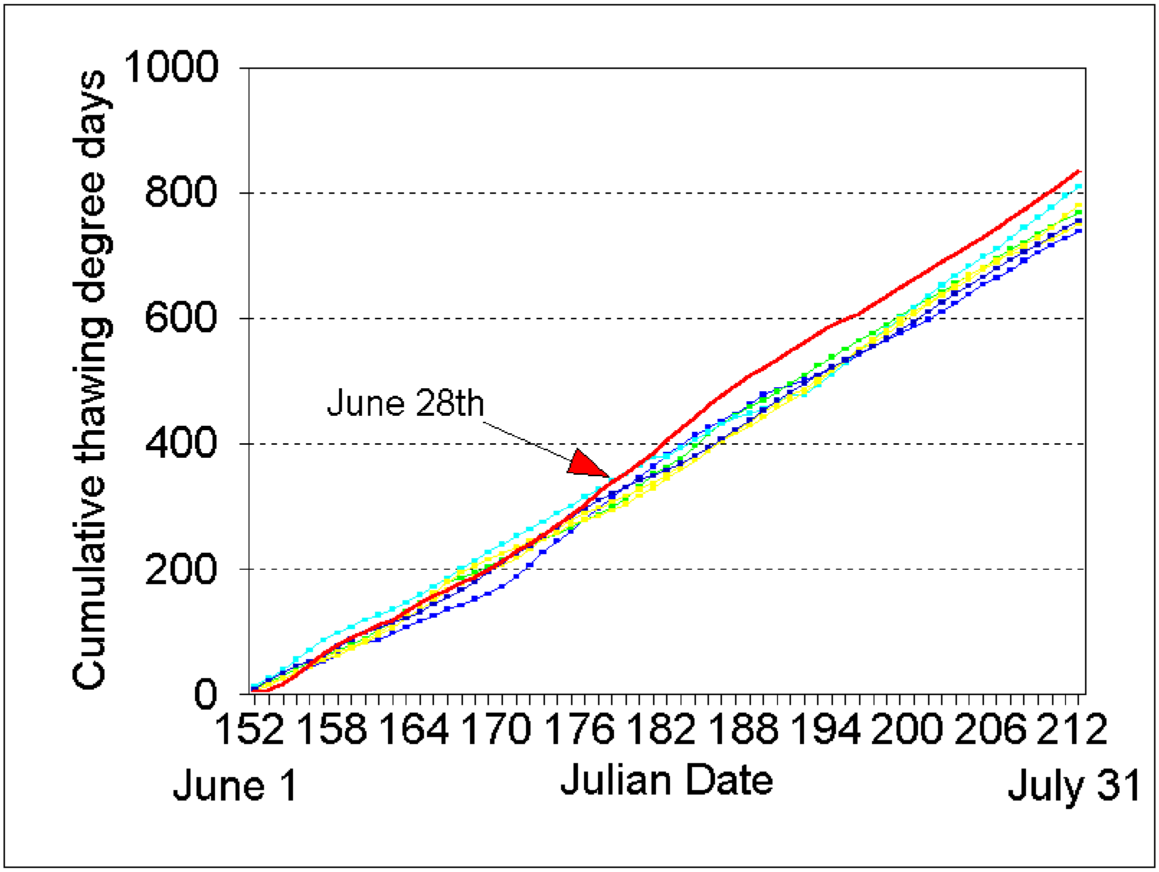

Figure 3. Cumulative thawing degree days for the months of June and July for Denali National Park headquarters, for the years 1991-1997 (red line shows 1997 values).

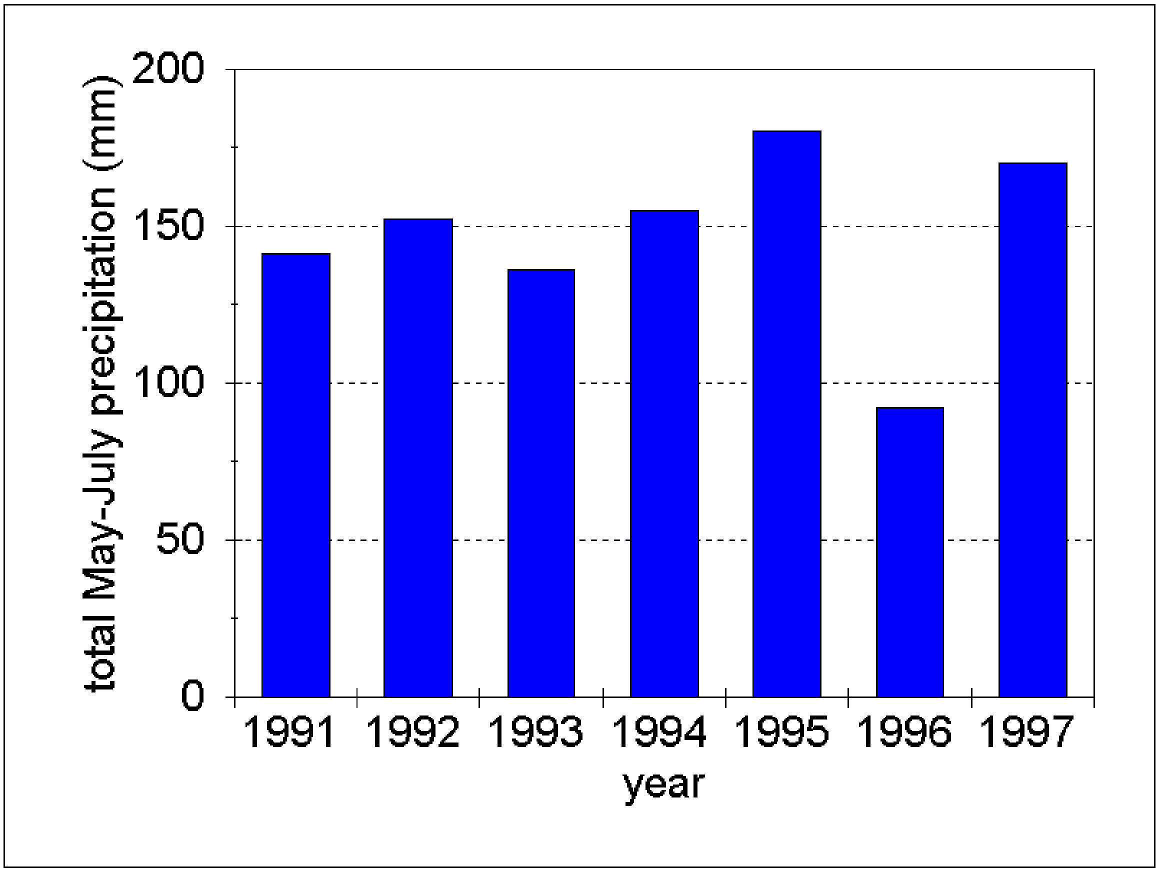

Figure 4. Total precipitation for May through July recorded at Denali National Park headquarters, Alaska.

Figure 5. Histogram showing size-class distribution of white spruce individuals in vegetation plots at the forest site in Rock Creek watershed of Denali National Park, Alaska.

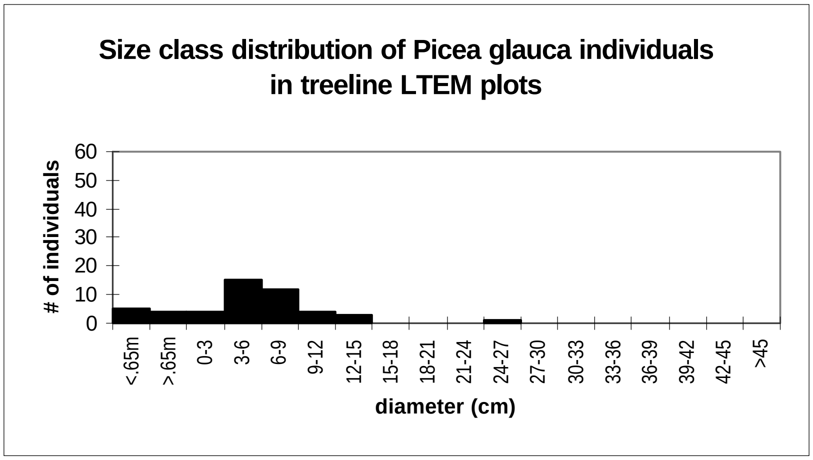

Figure 6. Histogram showing size-class distribution of white spruce individuals in vegetation plots at the treeline site in Rock Creek watershed of Denali National Park, Alaska.